

Record Hill Wind, LLC // Natural Resources Protection Act  
Construction of 50.6 megawatt wind energy development - Roxbury

Excerpts from the Department's License Record – Shadow Flicker

- Excerpts from application (12/08)
- Excerpt from application – Revision associated with change to Siemens turbine (6/17/2009)

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Section 26: MDEP NRPA/Site Location of Development Combined Application  
Record Hill Wind Project, Oxford County, Maine

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**Section 26**  
**Shadow Flicker**

## 1.0 Introduction

Shadow flicker from wind turbines is the effect resulting from the shadows cast by the rotating blades of the turbine on sunny days. The effect may be more or less pronounced depending on the intensity of the sun/shadow contrast and the distance from the turbines to a receptor. The effect is most pronounced during sunrise and sunset on clear days, and on receptors closer than 1,000 feet to a turbine.<sup>1</sup> At distances of 1,000 meters from turbines, the results of shadow flicker become unperceivable.

## 2.0 Analysis

The 22 potential turbine sites were modeled using the WindPRO software model. This software is designed to simulate the path of the sun over the course of a year in order to predict the area where shadow flicker is likely to occur. It is a worst case prediction, assuming the sun is shining each day, and does not take into account vegetation screening between a turbine and a receptor. It also assumes that the turbines are always operating and facing perpendicular to the receptor. See Appendix 26-1 for the complete shadow flicker report and illustrative maps.

The Record Hill Wind Project (Project) is situated such that no structures are located within 1,000 feet of a turbine. In fact, the nearest residence is located approximately 2,345 feet from the turbine string. Record Hill Wind LLC hired EAPC, LLC to conduct a shadow flicker analysis designed to assess any potential impact to residences in the vicinity of the Project. Their analysis quantified impacts out to 1,000 meters, well beyond the 1,000-foot distance referenced in the Site Location of Development Act application instructions.

## 3.0 Conclusion

The shadow flicker analysis identified four potential receptors. Each of these receptors are located south of the turbine string. Of the four potential shadow flicker receptors analyzed using the WindPRO software, none showed a possibility of any shadow flicker impact. The potential shadow flicker impact from this proposed project appears to be non-existent.

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<sup>1</sup> Environmental Impacts of Wind Energy Projects, National Academies Press, 2007, p. 160.

**Appendix 26-1**

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# EAPC WIND ENERGY SERVICES, LLC

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## SHADOW FLICKER ANALYSIS

### Record Hill Wind Project

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### **Report Update**

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### **Revision History**

Revision No.	Revision Purpose	Date	Revised By
0	Original	10-24-08	J. Simard
1	1,000 ft. Modeling	10-28-08	J. Simard
2	1,000 m Modeling	10-31-08	J. Simard

## 1. EXECUTIVE SUMMARY

EAPC Wind analyzed potential shadow flicker impacts to nearby residences from the Record Hill Wind Farm in Roxbury, Maine. EAPC Wind utilized the assumption that at a distance of 1,000 meters or further from a wind turbine, shadow flicker becomes unperceivable. There are four residences within 1,000 meters from a wind turbine, all located south of the wind turbines, making it impossible for a wind turbine to block the sun's rays and create a shadow. EAPC Wind concluded that there would be no shadow flicker impacts to the four residences within the modeled area.

## 2. INTRODUCTION

Record Hill Wind LLC (Client) proposes to install twenty-two wind turbines in the Town of Roxbury, Maine. EAPC Wind Energy Services, LLC (EAPC Wind) analyzed potential shadow impacts on nearby residences (receptors) within the Project.

EAPC Wind's analysis identified and measured the level and impact of shadow from the Project on the receptors.

## 3. BACKGROUND

Shadow flicker from wind turbines occurs when rotating wind turbine blades pass between the sun and the viewer. Shadow flicker is generally experienced in areas near wind turbines where the distance between the viewer and blade is short enough that the glare from the sunlight is insufficient to conceal the blade. When the blades rotate, this shadow creates a visual pulsing effect with the sun known as shadow flicker. From longer distances, however, the wind turbine covers an increasingly smaller portion of the sun and light rays will "recombine" to eliminate the shadow flicker effect. Shadow flicker is greatest in the winter months as the angle of the sun is low and casts a longer shadow. The effect is limited to the hours close to sunrise and sunset when the sun is near the horizon.

A number of factors influence shadow flicker on the shadow receptors. One consideration is the environment around the shadow receptor. Obstacles such as terrain, trees, or buildings between the wind turbine and a potential shadow flicker receptor significantly reduce or eliminate shadow flicker effects. Also, deciduous trees affect the ability of shadow flicker to

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reach the viewer depending on whether such trees have leaves or not. These obstacles and seasonal variations were not considered in the modeling.

Another consideration is the time of day when shadow flicker occurs. As an example, a factory or office building would not be affected if all the shadow impact occurred outside of business hours, whereas it would be more acceptable for private homes to experience shadow impact during working hours, when the family members are at work/school.

Lastly, the climate also has to be considered when assessing shadow flicker. In areas with high rates of overcast weather there would be less shadow flicker. As well, when the wind is not blowing, the wind turbine blades do not move and therefore no shadow flicker occurs. Statistics regarding the wind conditions and sunshine probability were not modeled in this study.

#### **4. METHODOLOGY**

EAPC Wind utilized WindPRO, a sophisticated wind modeling software program, to perform the shadow flicker calculations and results. WindPRO calculated how often and in which intervals a specific receptor or area could be affected by shadows generated by one or more wind turbines.

The calculation of the potential shadow impact at a given shadow receptor is carried out by simulating the environment near the wind turbines and the shadow receptors. The position of the sun relative to the turbine rotor disk and the resulting shadow is calculated in time steps of one minute throughout a complete year. If the shadow of the rotor disk (which in the calculation is assumed solid) at any time casts a shadow on a receptor window, which has been defined as a shadow receptor object, then this step will be registered as one minute of potential shadow impact.

This model assumes that shadow flicker can only occur when at least 20% of the sun is covered by the wind rotor disk.

These calculations take into account the following variables:

- Wind turbine location and elevation
- Wind turbine dimensions
- Receptor location and elevation

#### 4.1. WIND TURBINE LOCATION AND ELEVATION

The location and elevation of a wind turbine in relation to a receptor is one of the largest factors in determining shadow flicker impacts. A line-of-sight is required for shadow flicker to occur. Also, the distance a wind turbine is from a receptor will have an impact on shadow flicker intensity.

The locations and elevations of the wind turbines are shown below. All coordinates are presented in UTM WGS 1984 Zone 19N.

WTG #	X	Y	Elev. (m)
1	370696	4947998	594.4
2	370648	4947770	570.5
3	370651	4947512	578.8
4	370616	4947275	596.5
5	370665	4947048	624.6
6	370751	4946842	635.0
7	370949	4946615	651.0
8	370760	4946358	605.0
9	370740	4946124	613.3
10	370667	4945892	581.8
11	370548	4945664	561.0
12	370807	4944502	549.1
13	370754	4944272	551.5
14	370700	4944040	562.3
15	370693	4943809	576.8
16	370901	4943553	600.3
17	370592	4945420	537.0
18	370553	4949065	609.6
19	370539	4948846	601.2
20	370576	4948630	607.6
21	370564	4948411	580.6
22	370666	4948206	581.0

#### 4.2. WIND TURBINE DIMENSIONS

A wind turbine's total height and rotor diameter were included in the WindPRO shadow flicker model. The higher the turbine, the more likely shadow flicker could have an effect on the local receptors, as the ability to clear obstacles (such as trees or hills) is greater. The larger the rotor diameter, the more area on the ground could be affected by shadow flicker.

The dimensions of the Clipper C96 wind turbine used for this study are shown below.

Turbine Model	Rated Capacity (MW)	Hub Height (m)	Rotor Diameter (m)	Blade Tip Height (m)
Clipper C96 Liberty	2.5	80	96	128

#### 4.3. SHADOW RECEPTOR LOCATION AND ELEVATION

As with wind turbine location, the elevation, distance, and direction from a wind turbine are large factors in determining the significance of shadow flicker impact. EAPC Wind modeled shadow flicker with receptors one meter high by one meter wide and the worst-case orientation which assumes all receptors face the turbine directly.

EAPC Wind ran the shadow flicker model to assume that at 1,000 meters (3,280 feet) or further from a wind turbine, shadow flicker impacts are irrelevant. This number is widely used as a 'no-impact zone' threshold and is over three times the distance recommended by the Maine Department of Environmental Protection. According to the Maine DEP, "At distances of greater than 1,000 feet between wind turbines and receptors, shadow flicker usually only occurs at sunrise or sunset when the cast shadows are sufficiently long. For situations where the rotor plane is in line with the sun and receptor (as seen from the receptor), the cast shadows will be very narrow (blade thickness), of low intensity, and will move quickly past the stationary receptor".

#### 5. SHADOW FLICKER RESULTS

EAPC Wind modeled all four residential buildings that lie within 1,000 meters of a wind turbine. The structures modeled were field-verified as residential dwellings.

There are four receptors in the project area within 1,000 meters of a wind turbine. Of those, none have the potential for shadow flicker hours due to their southern proximity to the wind turbines.

The receptors modeled in the WindPRO shadow flicker calculations are outlined below.

X	Y	Receptor #	Annual Hours of Shadow Flicker	Dist to Nearest Turbine (m)
370610	4942597	463	0	1000
370530	4942742	465	0	891
370898	4942599	467	0	954
371064	4942857	468	0	715

Additional modeling to account for the Maine DEP standard was not performed as there are no receptors in the project area within 1,000 feet of a wind turbine (closest receptor is 2,345 feet away).

### 5.1. ADDITIONAL FACTORS

This analysis does not take into account the predicted wind speed and direction at each turbine, average cloud cover, and obstacles. These factors would reduce the operational time, line-of-sight, and shadow size cast by a wind turbine. These calculations also assume each residence is directly facing a wind turbine. Therefore these estimates may be more conservative than what would likely be experienced by a given receptor. As such, it is likely receptors will be less impacted due to the following factors:

Wind Speed: Rotors will only turn when wind speeds are above appropriate levels (typically 3.5 m/s). This analysis assumes that the wind is always blowing at a sufficient speed to turn the rotors, which results in a conservatively high estimate of shadow flicker impacts hours.

Wind Direction: During operation the rotors will face into the wind and will continually orient themselves as the wind direction changes.

The wind direction relative to the sun's location is key to whether shadow flicker impacts can occur. This analysis assumes that the wind is always oriented to produce shadow effect at a receptor location.

Average Cloud Cover: Average climate conditions for the project area would decrease shadow flicker impacts due to the sporadic presence of clouds, fog, and haze. The worst-case model assumes every day of the year has clear skies and perfect visibility.

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Receptor Direction and Dimensions: Receptor orientations and dimensions are variable. When modeling each shadow receptor's actual direction and window dimensions, shadow flicker impacts typically decrease.

Resident Occupancy: The estimate of hours assumes that a person is always present to observe the shadow flicker impacts. Seasonal residences would typically have a lower chance of being effected by shadow flicker due to the lack of occupancy. Furthermore, residences that are lived in year round may not always have occupants when shadow flicker is present.

## 6. CONCLUSIONS

EAPC Wind was able to predict the annual shadow flicker hours for all residences within 1,000 meters of a wind turbine as zero, as their southern proximity to the wind turbine exclude the possibility for shadows to occur.

In conclusion, for the reasons set forth in this report, the potential shadow flicker impact from this proposed Project appears to be non-existent.

## **EAPC Wind, LLC**

Based in Norwich, VT, EAPC Wind Energy Services, LLC is a joint venture between EAPC, LLC (EAPC) and Vermont Windpower International, LLC (VWI).

EAPC Wind provides a wide range of wind energy consulting services to wind developers both large and small, electric utilities, communities, economic development groups, universities and Native American tribes.

The staff and principals of EAPC Wind have 75 years worth of combined experience in wind energy consulting, development, and manufacturing.

EAPC has provided wind engineering and consulting services on more than 5,000 MW of wind farm development in the Americas, Europe, and beyond.

Services include site prospecting, feasibility studies, meteorological tower siting and erection, wind resource assessment, data collection and analysis as well as wind farm layout and wind turbine array analysis.

EAPC Wind also provides due diligence services to investors with regard to wind resource assessments and energy production estimates.

EAPC Wind has a staff of experts in wind resource modeling and is the sole North American distributor of WindPRO, the world's leading software tool used in the design and analysis of wind farms.

EAPC Wind has had experience with project due diligence review for major financial institutions and has reviewed wind resource and energy production assessments, contracts, and turbine suitability studies for projects throughout the country. EAPC has also assisted project owners and financiers with component supply issues and technical review of turbine technologies.

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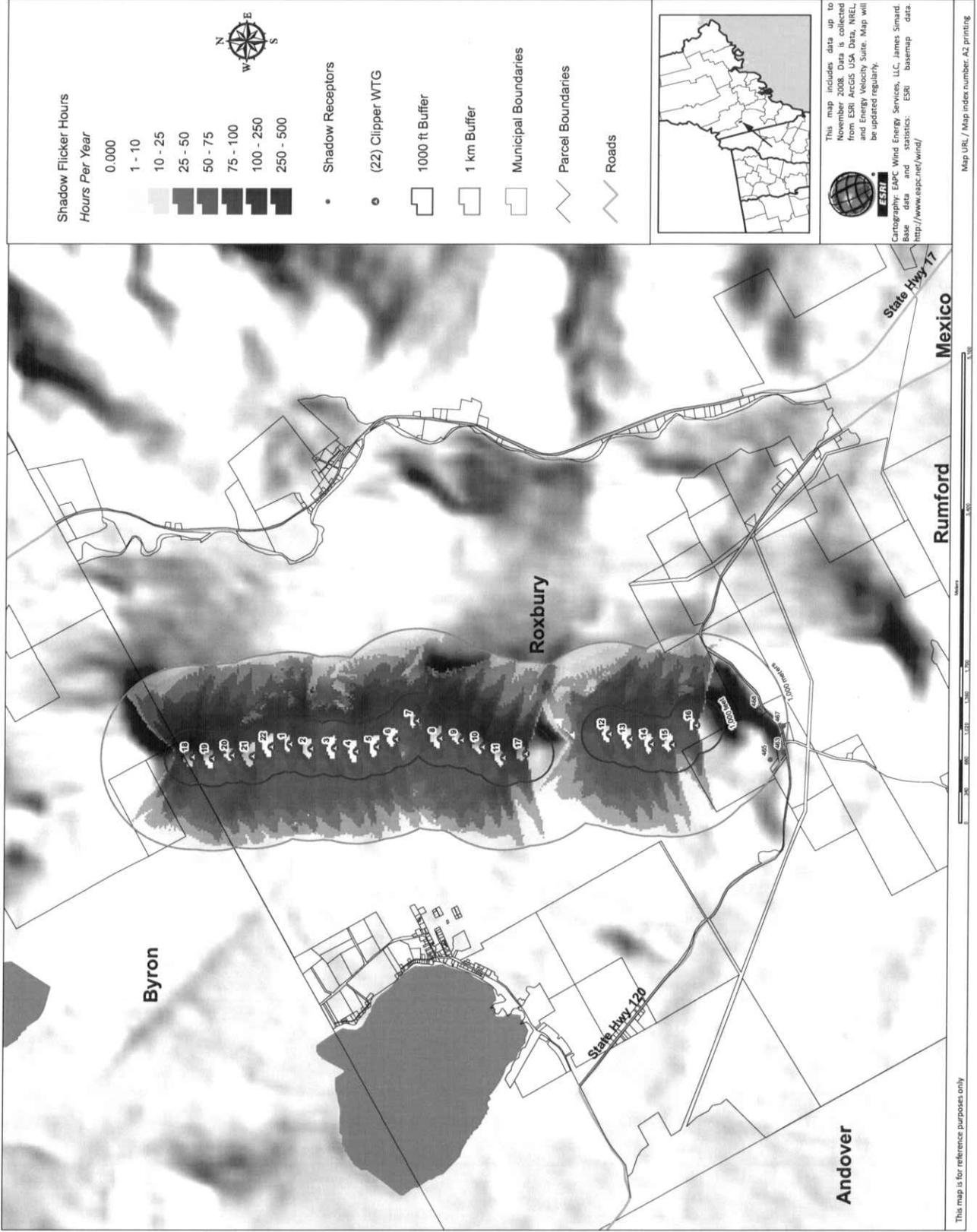
November 2008

Client:  
Record Hill Wind LLC

EAPC Wind Energy Services, LLC

# RECORD HILL WIND FARM SHADOW FLICKER HOURS- RECEPTORS

# EAPC WIND ENERGY SERVICES, LLC



This map is for reference purposes only

# EAPC WIND

ENERGY SERVICES, LLC

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## SHADOW FLICKER ANALYSIS *ADDENDUM*

### Record Hill Wind Project

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2009

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0	Original	10-24-08	J. Simard
1	1,000 ft. Modeling	10-28-08	J. Simard
2	1,000 m Modeling	10-31-08	J. Simard
3	Addendum SWT-2.3-93	5-3-09	A. Pollock

## 1. INTRODUCTION

Wagner Forest Management (Client) proposes to install twenty-two wind turbines in the Town of Roxbury, Maine. EAPC Wind Energy Services, LLC (EAPC Wind) analyzed potential shadow impacts on nearby residences (receptors) within the Project. The original report was based on the Clipper C96 wind turbine. For this Addendum to the original report, EAPC Wind reanalyzed the shadow flicker for the Siemens SWT-2.3-93 wind turbine.

EAPC Wind's analysis identified and measured the level and impact of shadow from the Project on the receptors. The predicted hours per year of shadow flicker impact was calculated for each receptor.

All the assumptions and qualifications of the previous report also apply to this addendum. The locations of the turbines and receptors remained the same as for the original study.

### 1.1. Wind Turbine Location and Elevation

The location and elevation of a wind turbine in relation to a receptor is one of the largest factors in determining shadow flicker impacts. A line-of-site is required for shadow flicker to occur. Also, the distance a wind turbine is from a receptor will have an impact on shadow flicker intensity.

The locations and elevations of the wind turbines are shown below. All coordinates are presented in UTM WGS 1984 Zone 19N.

WTG #	X	Y	Elev. (m)
1	370696	4947998	594.4
2	370648	4947770	570.5
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19	370539	4948846	601.2
20	370576	4948630	607.6
21	370564	4948411	580.6
22	370666	4948206	581.0

**1.2. Wind Turbine Dimensions**

EAPC Wind re-modeled the potential shadow flicker impact using the Siemens SWT-2.3-93 turbine. The turbine has the following key dimensions.

Turbine Model	Rated Capacity (MW)	Hub Height (m)	Rotor Diameter (m)	Blade Tip Height (m)
Siemens SWT-2.3-93	2.3	80	92.6	126.3

**2. SHADOW FLICKER RESULTS**

All the assumptions and qualifications of the previous report also apply to this addendum. The locations of the turbines and receptors remained the same as for the original study.

There are only four residential buildings that lie within 1,000 meters of a wind turbine. The structures modeled were field-verified as residential dwellings. EAPC Wind modeled these four receptors and found that none have the potential for shadow flicker hours. This is because they are south of any wind turbines and no turbines will ever be between the sun and these receptors, excluding any possibility of shadow flicker impact.

The receptors modeled in the WindPRO shadow flicker calculations are outlined below.

X	Y	Receptor #	Annual Hours of Shadow Flicker	Dist to Nearest Turbine (m)
370610	4942597	463	0	1000
370530	4942742	465	0	891
370898	4942599	467	0	954
371064	4942857	468	0	715

Additional modeling to account for the Maine DEP standard was not performed as there are no receptors in the project area within 1,000 feet of a wind turbine. The closest receptor is 2,345 feet (715 m) away.

### 3. CONCLUSIONS

EAPC Wind remodeled the Record Hill Wind farm shadow flicker using the Siemens SWT-2.3-93 wind turbine. All 4 buildings that lie within 1,000 m of a turbine were modeled. As with the Clipper C96 turbine, EAPC Wind found that there will be no shadow flicker impact at these buildings, as they lie to the south of the wind farm.

In conclusion, for the reasons set forth in this report addendum, the potential shadow flicker impact from this proposed Project appears to be non-existent.